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(54) **CONFIGURABLE WEIGHTING OF REPRESENTATIONAL CONTROLS TO OBTAIN AN OPTIMAL ROUTING SOLUTION**

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(57)   **ABSTRACT**

A method for delivering an optimal routing solution that considers the complete operational cost model in the optimization process is provided. The method utilizes heterogeneous service providers to service heterogeneous service points, where the service points are geographically dispersed. The method includes providing a plurality of service point profiles that define parameters associated with a plurality of service points; providing a plurality of service provider profiles, that define parameters associated with a plurality of service providers; providing a service point visit plan for the plurality of service points; and scoring a plurality of routing solutions to service the plurality of service points, utilizing the service point profiles and the service provider profiles. In addition, scoring controls are provided for assigning a cost to, or penalty, either linearly or non-linearly, selected parameters being either met or not met within any possible routing solution. The profiles, visit plan, and scoring controls are provided to a route engine that determines an optimal routing solution according to the scoring model.

Figure 1

Figure 3

Figure 2

Figure 4

Optimized Routing
User Interface

Service Provider
Service Point
Visit Plan
Scoring Model
Calendering
Schedule

410

Route Engine

Meta Heuristics

Heuristics

Anti-Niching

420

Representation
Model

Service point
profile

Service provider
profile

Scoring Model

Map DB

430

400
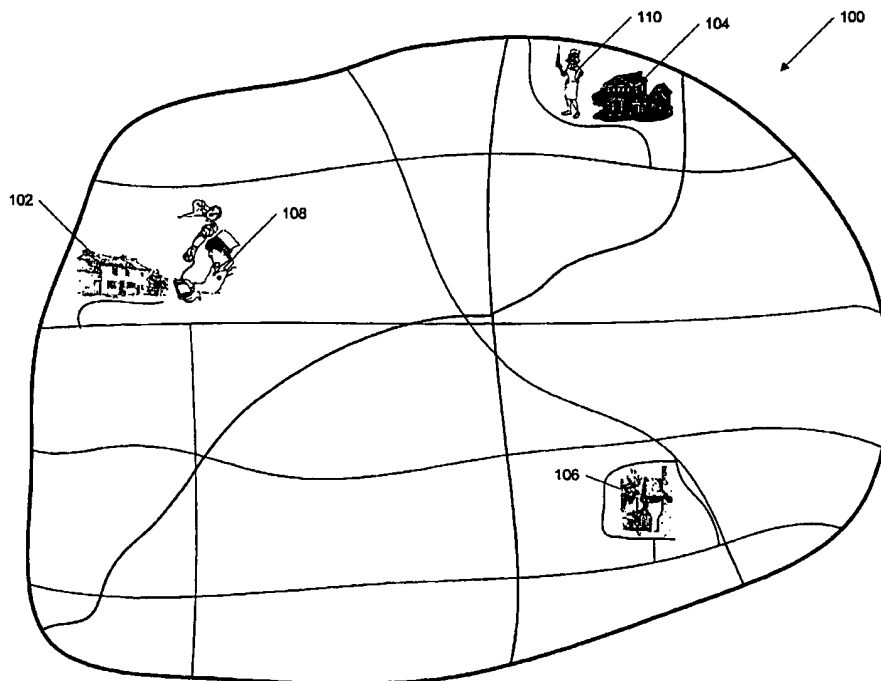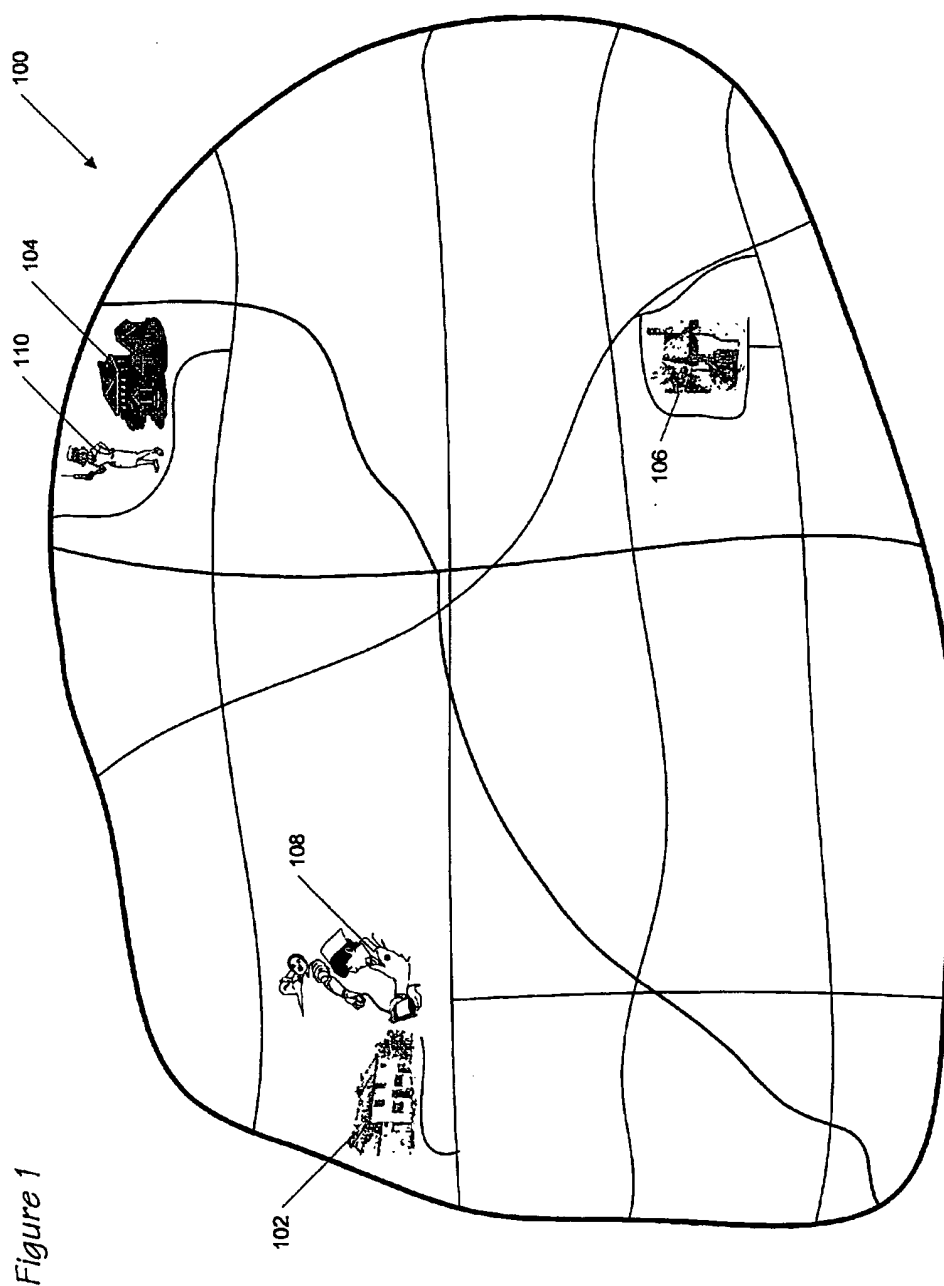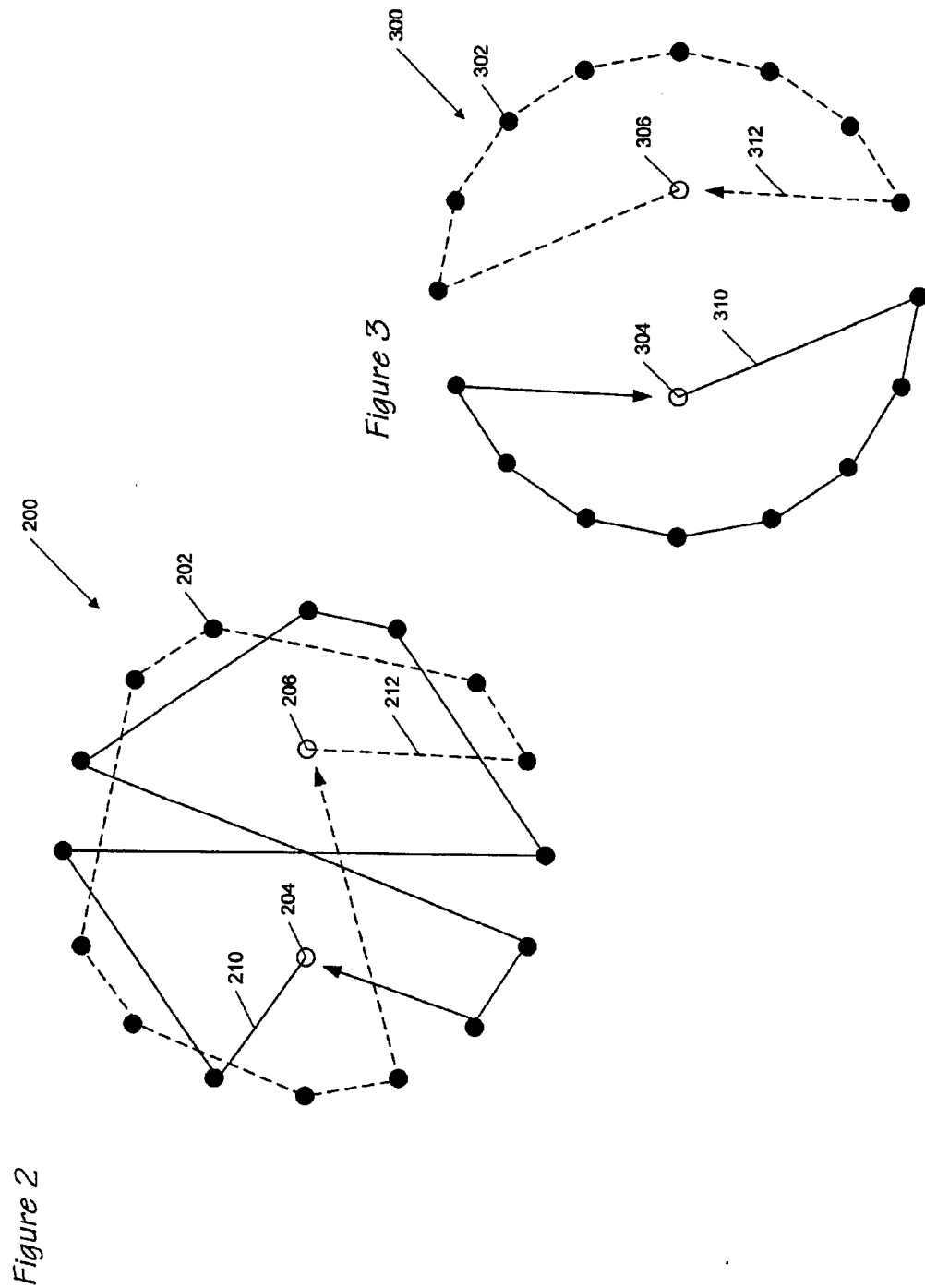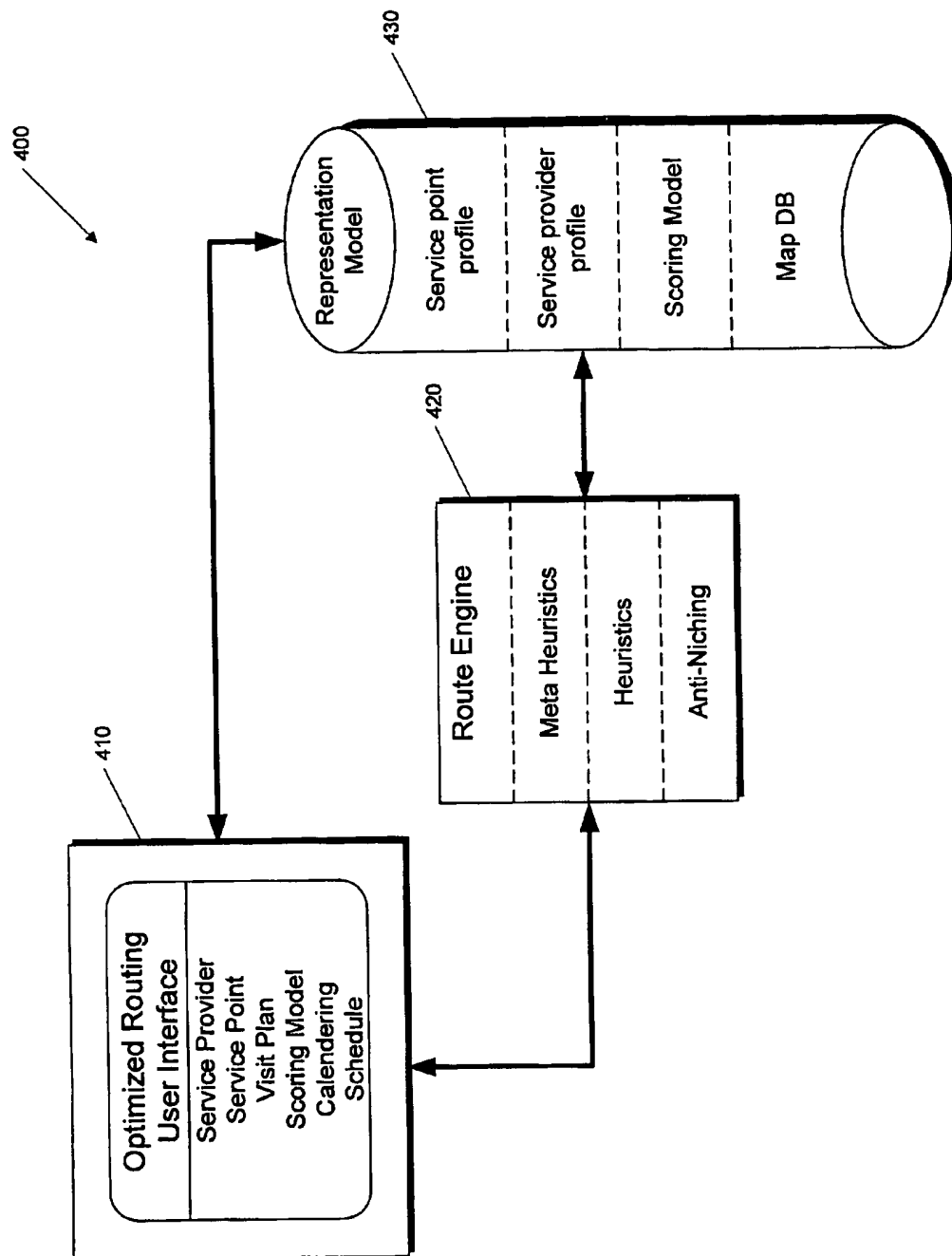
Figure 5
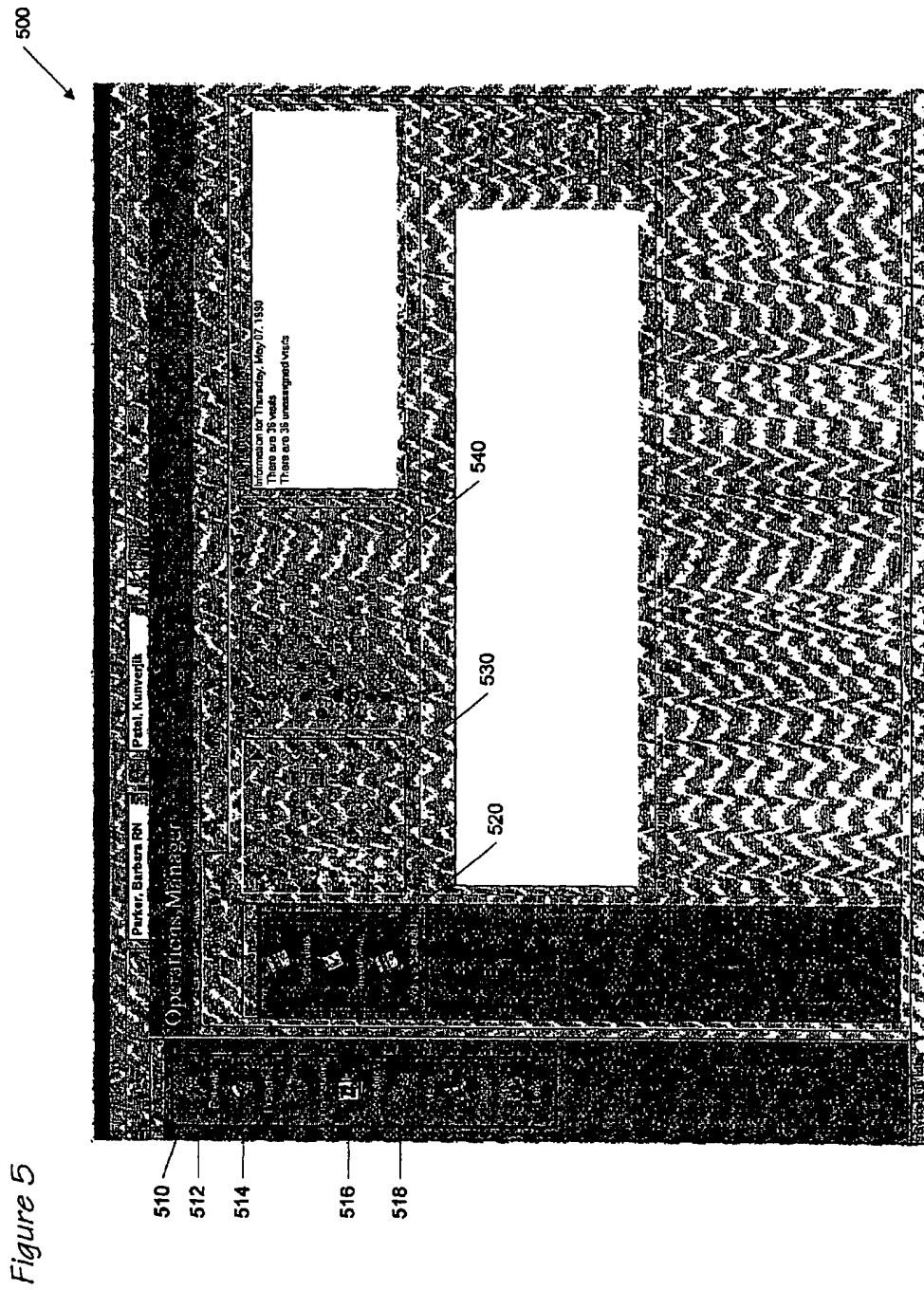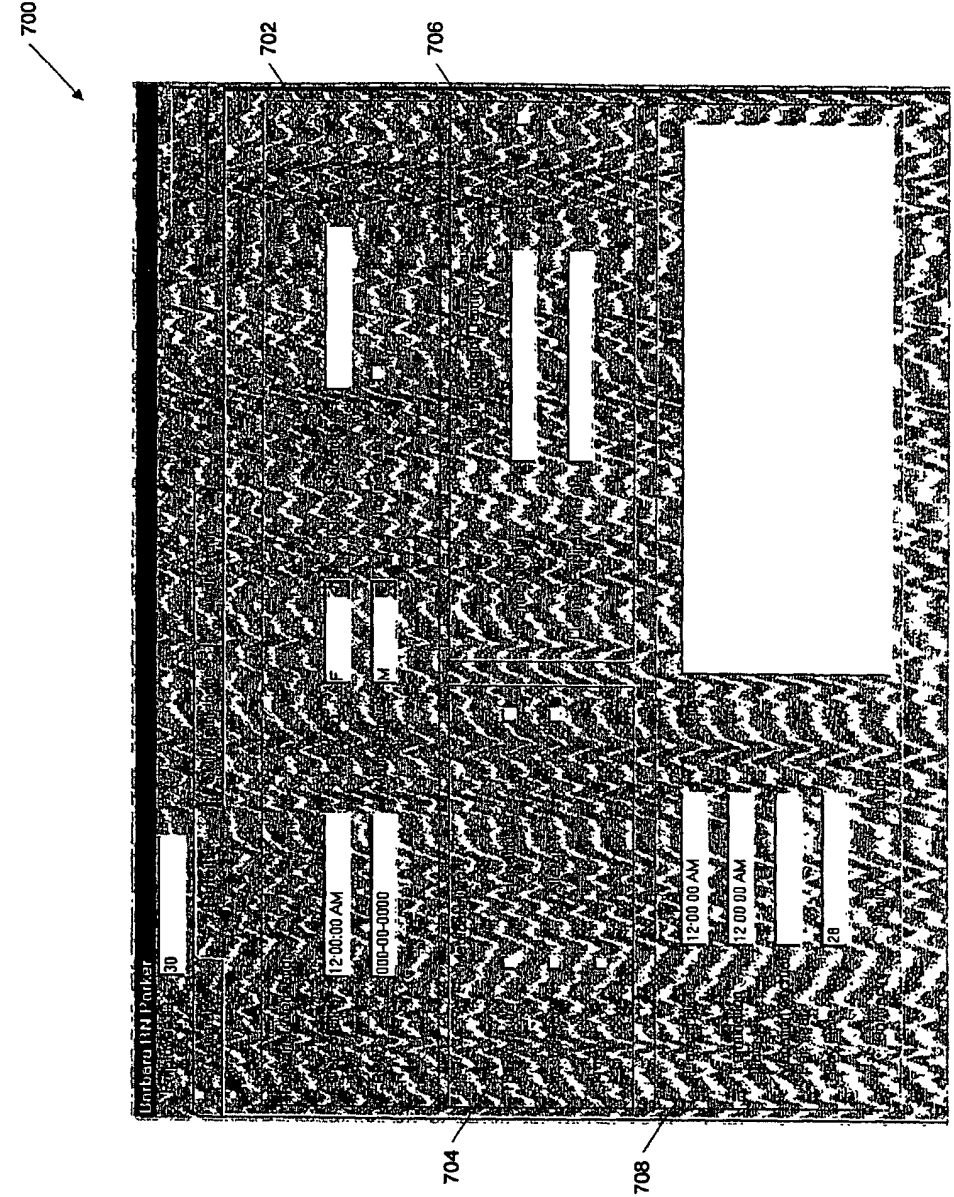
Figure 6

Figure 7

Figure 8

900
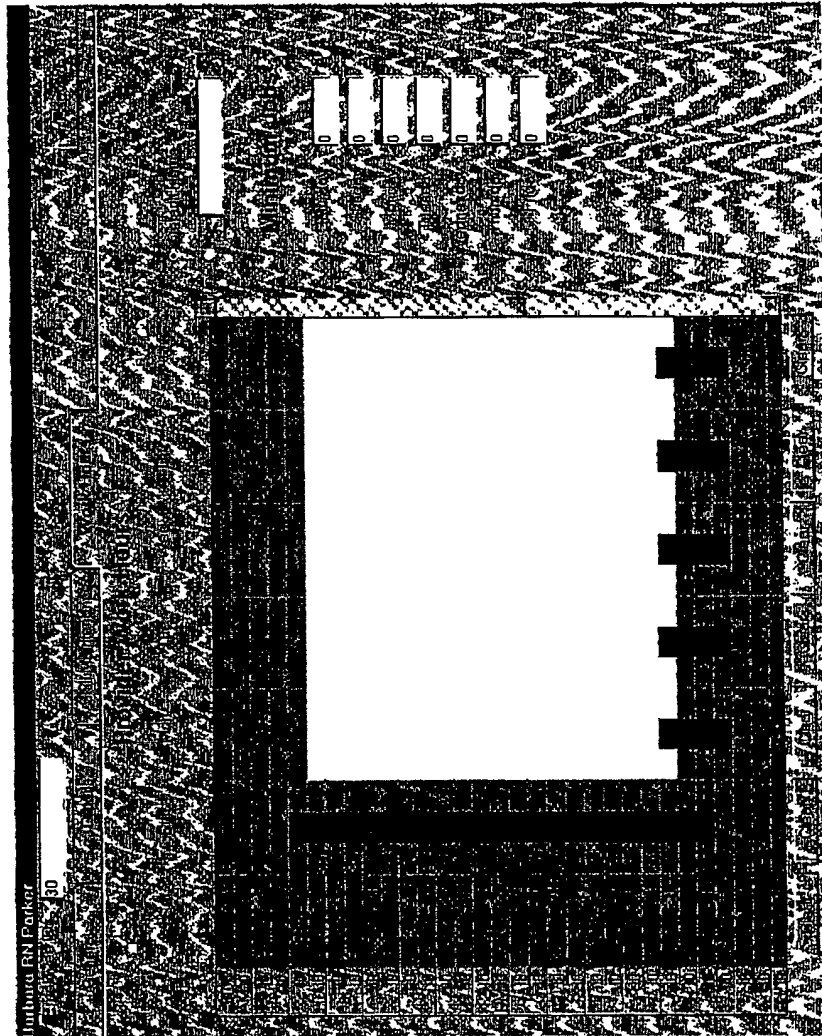
Figure 9

Figure 10

1100
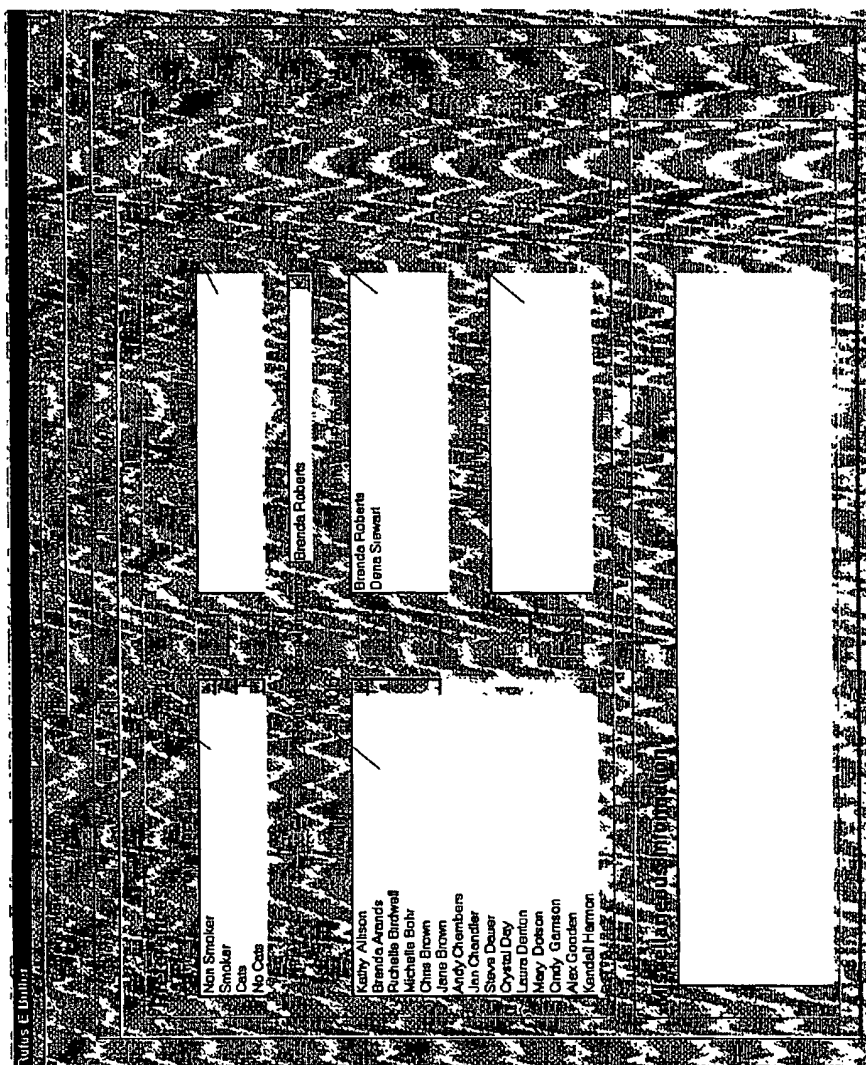
Figure 11
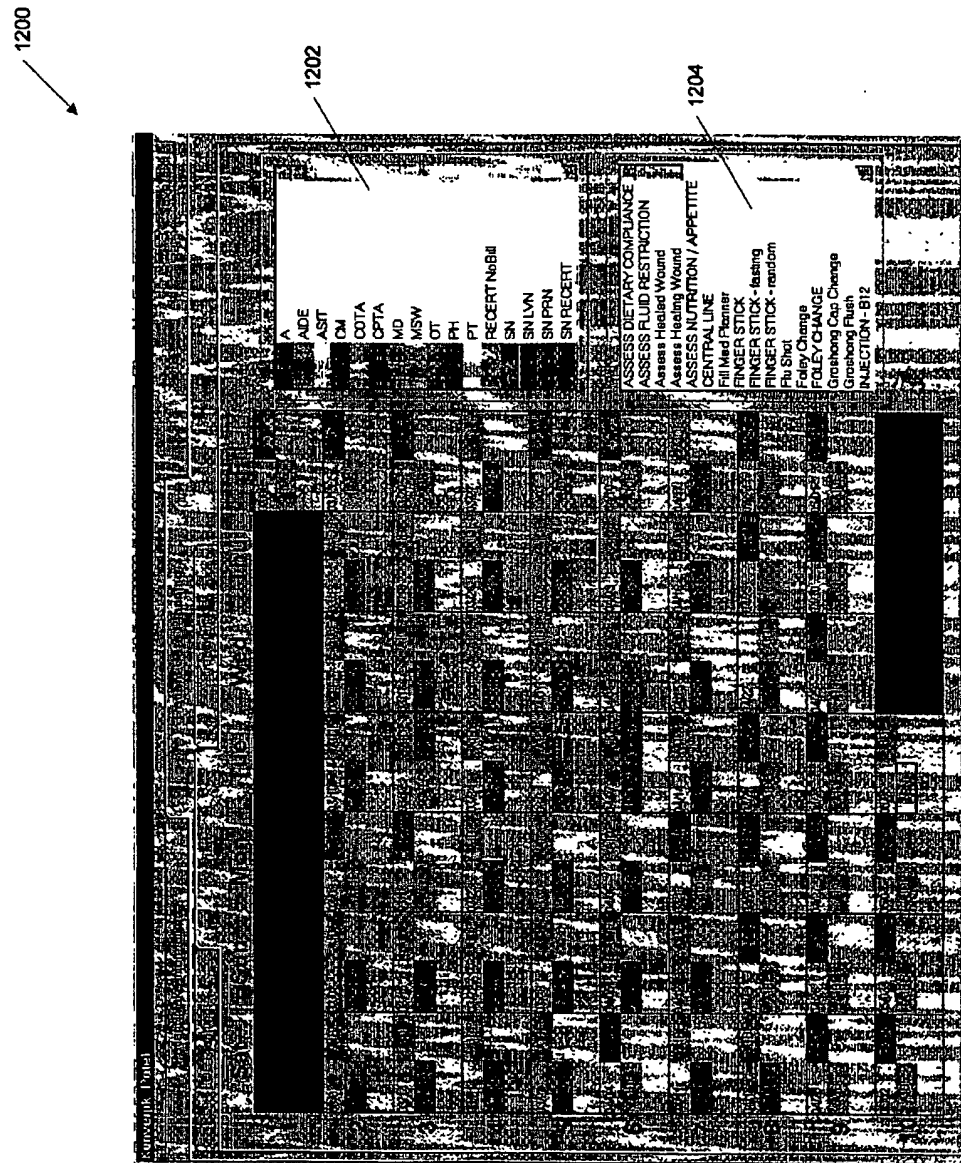
Figure 12

Figure 13

Figure 14

Figure 15

Figure 16

CONFIGURABLE WEIGHTING OF REPRESENTATIONAL CONTROLS TO OBTAIN AN OPTIMAL ROUTING SOLUTION

CROSS REFERENCE TO RELATED APPLICATION(S)

[0001] This application is a continuation-in-part of copending U.S. patent application, Ser. No. 09/087,828, filed May 29, 1998, entitled "REPRESENTATIONAL CONTROL FOR OPTIMAL ROUTING SOLUTION", and assigned to a common Assignee.

BACKGROUND OF THE INVENTION
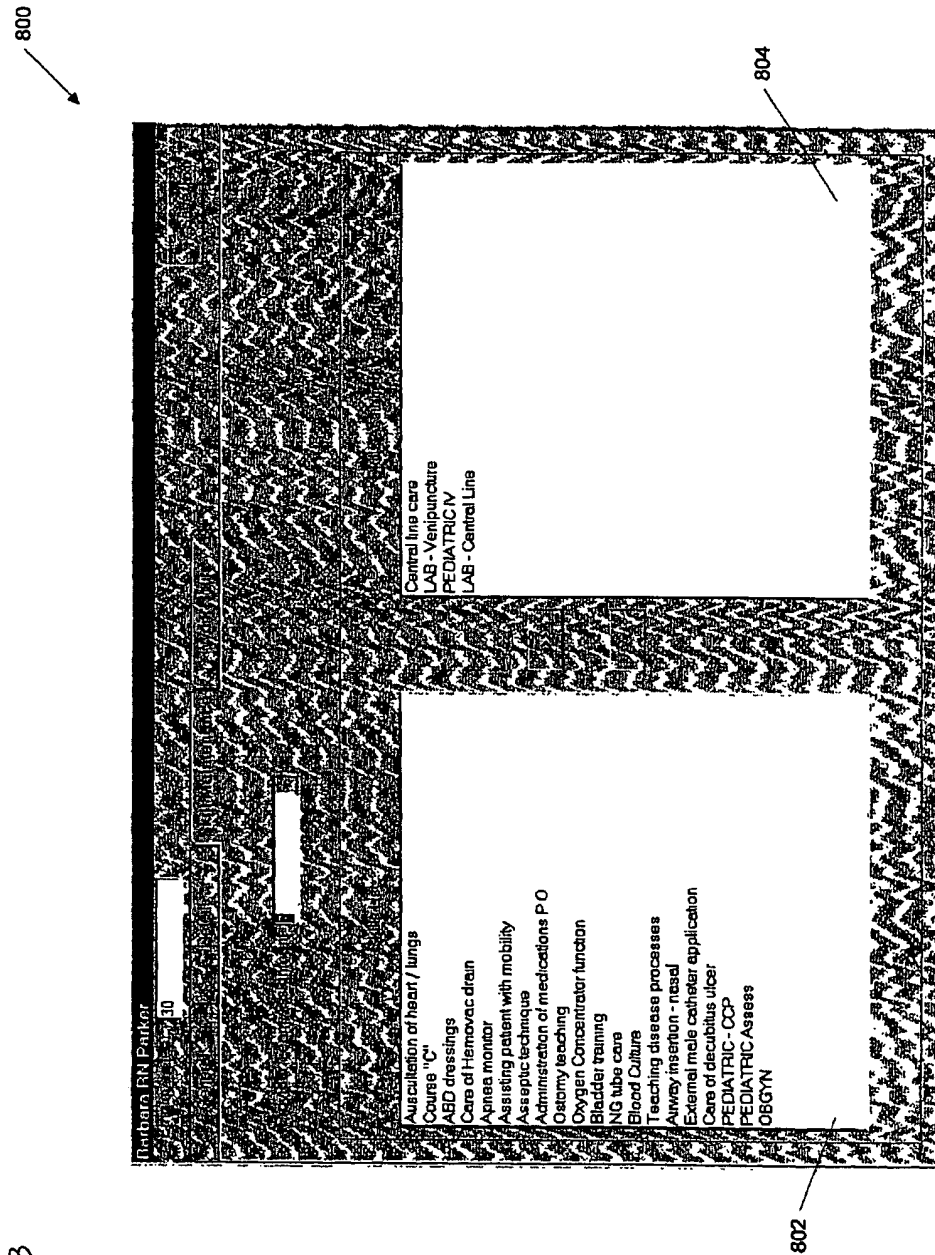
[0002] 1. Field of the Invention

[0003] This invention relates in general to the scheduling of resources to visit predefined service points, and more specifically to a weighting scheme within a computerized methodology for providing optimal routing solutions utilizing representational parameters for resources and service points.

[0004] 2. Description of the Related Art

[0005] The routing and scheduling of vehicles, personnel, and/or services represents an important cost component for many service indu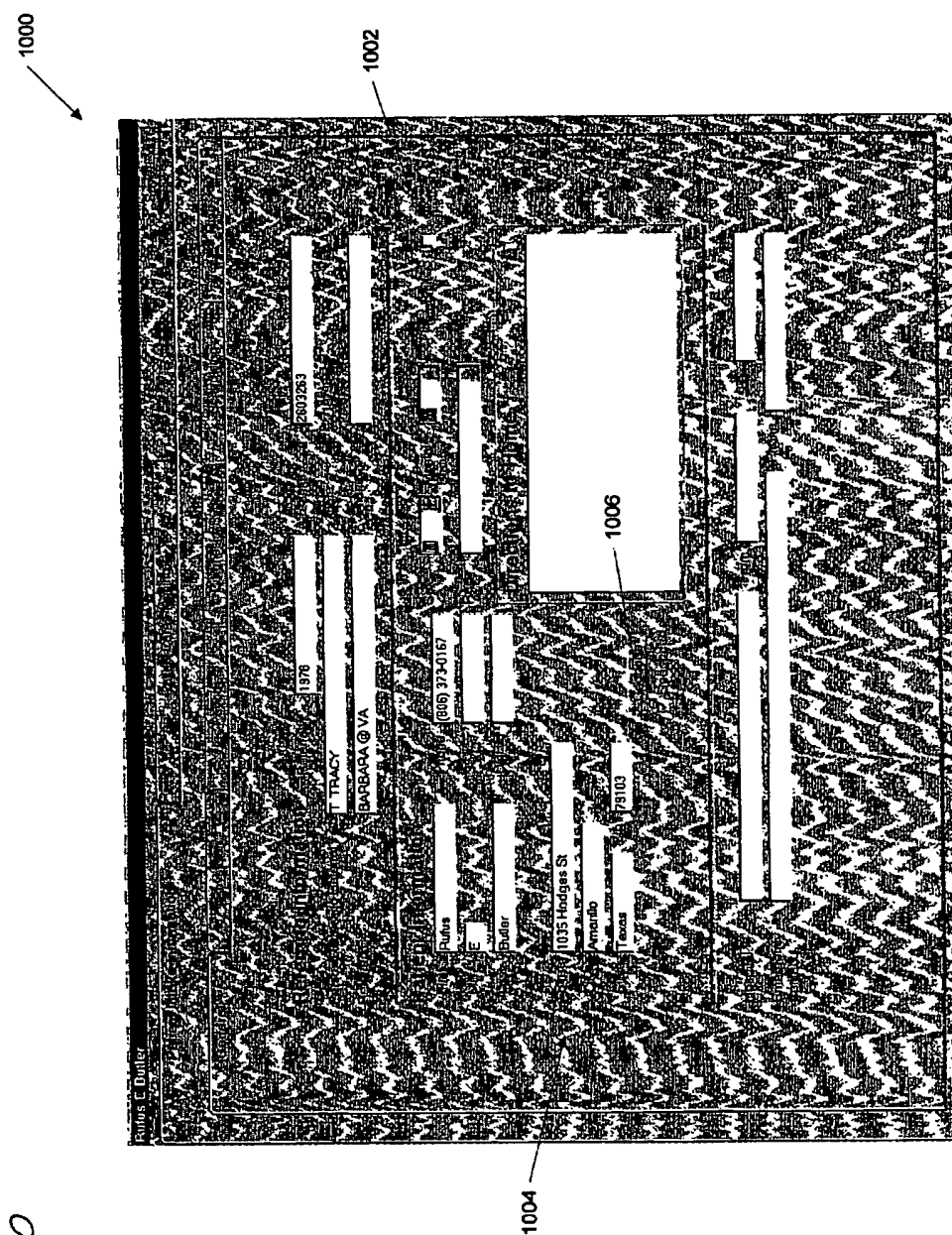stries. The utility industry (electric, gas, water), telephone and telecommunications industries, transportation industries (ground, air, water), mail and package delivery industries, courier services, and health care industry are all examples of businesses that have to schedule equipment or personnel to travel from one location to another, either to pick up or deliver people or packages, or to perform services, such as repairing a telephone or visiting a patient.

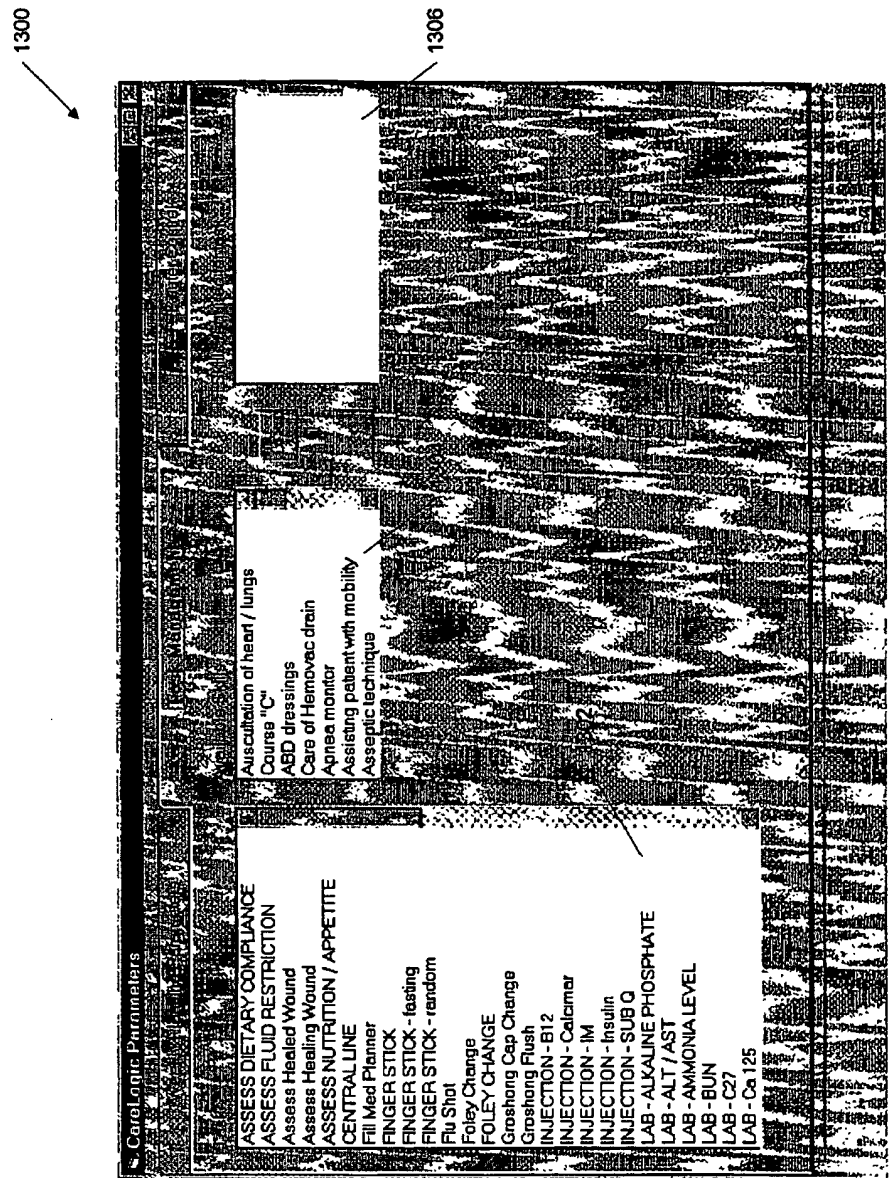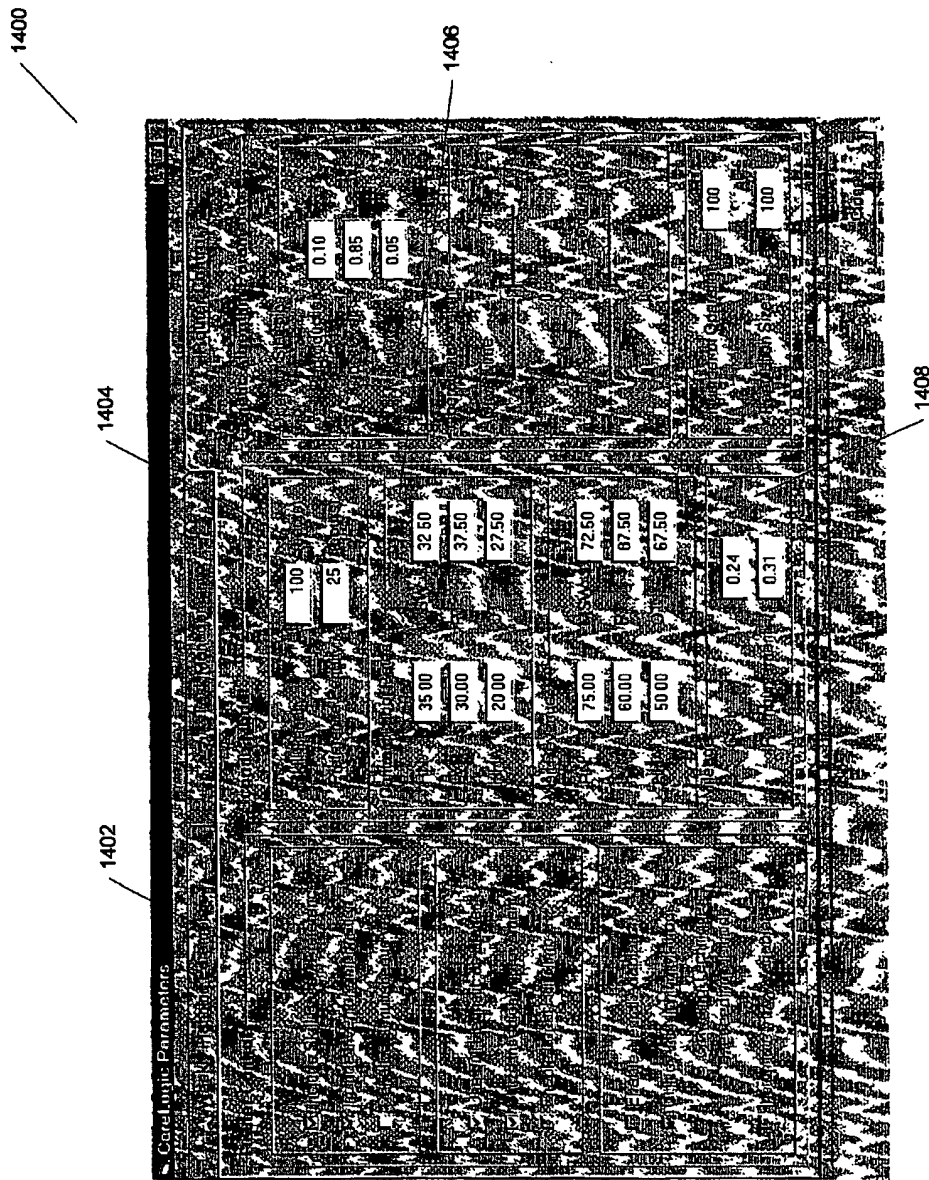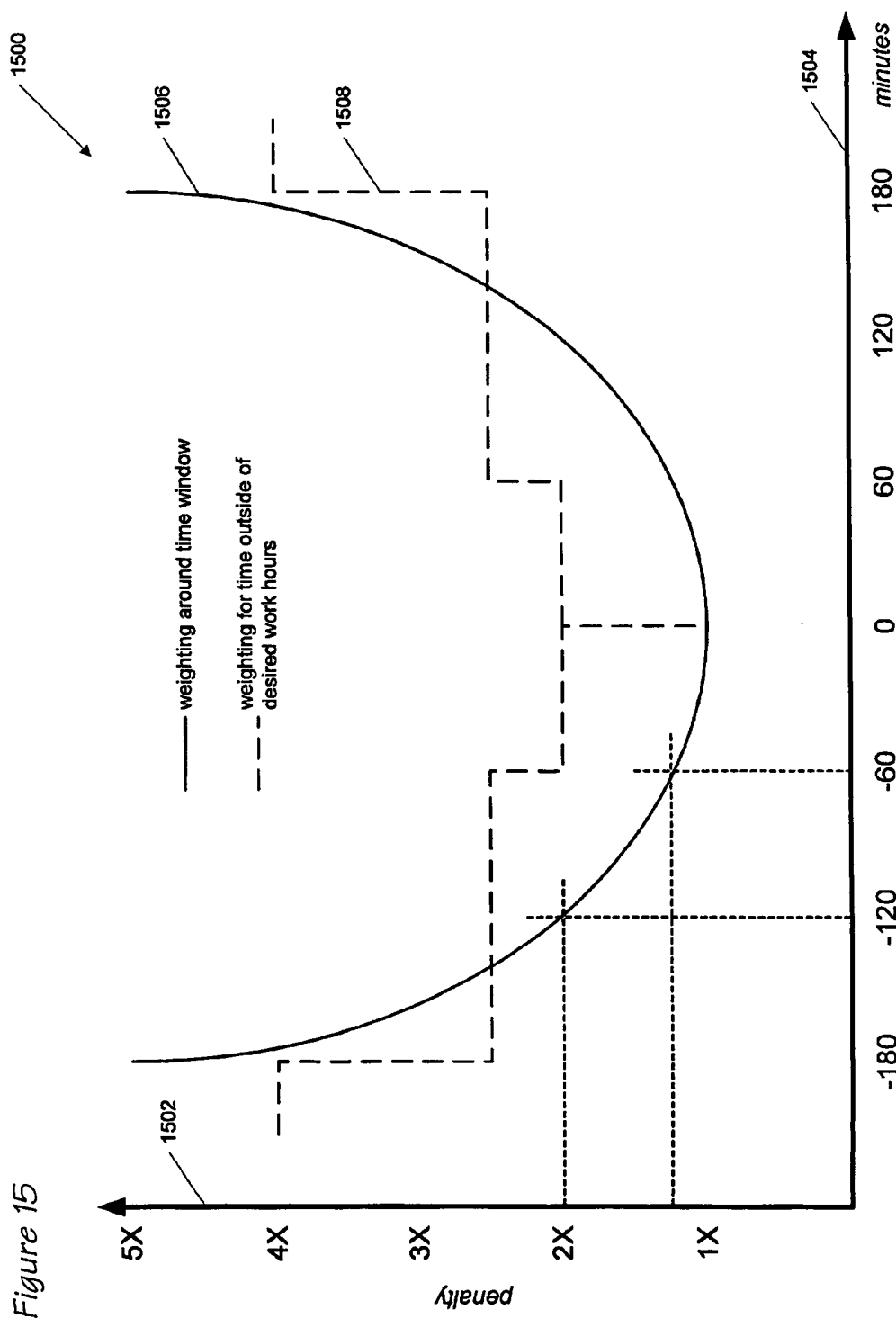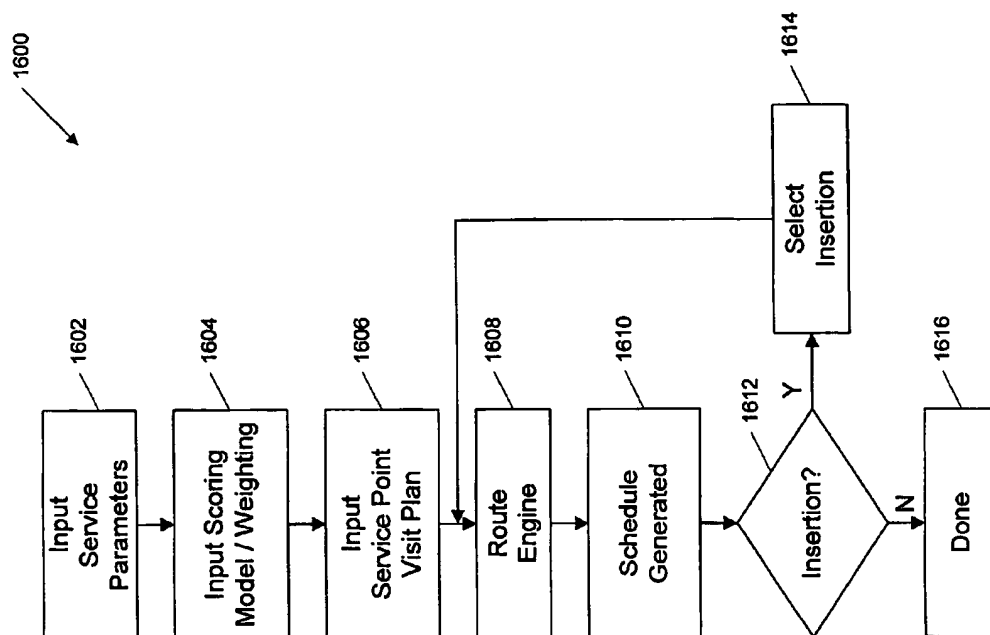[0006] Typically, when calculating optimum routing solutions for a particular industry, the methodology has been restricted to optimizing routes for a set of service providers originating from a common depot location, utilizing geographical distance as the sole factor in determining an optimal route. That is, systems are given a set of service providers at a common depot location, and a list of service points at which a service provider must make an appearance. The systems then generate a routing solution for the set of service providers that is optimal to reduce either travel distance, or travel time. For purposes of obtaining an optimum solution with these systems, all of the service providers are considered to have the same capabilities or skills, and all of the service points are treated as the same. That is, the systems view service points and service providers as homogeneous sets.

[0007] In addition, many systems are unable to provide routing solutions with any consideration of time. For example, when scheduling a package pickup from a major transportation company, or a utility hook up with a local utility provider, it is often impossible to obtain a commitment with respect to an anticipated time of service. Rather, the routing solutions used by such companies only guarantee that a service will occur before closing of a particular business day.

[0008] More recent advances have been made which allow for inclusion of time windows as a parameter to be used in obtaining an optimal routing solution. A time window defines a start time, and an end time, between which service

must be performed for a particular service point. One such solution is discussed in an article entitled "A New Optimization Algorithm for the Vehicle Routing Problem with Time Windows", by Desrochers, Desrosiers & Solomon, Vol. 40, No. 2, pages 342-354, 1992 Operations Research Society of America, which is incorporated herein by reference. However, such solutions only use geographic distance, and time windows to obtain an optimal routing solution for a homogeneous set of service providers, departing from a common depot location, for servicing a homogeneous set of service points.

[0009] The above described solutions, although attempting to reduce service costs by reducing either the travel distance or the travel time for a particular set of routes, have not proven satisfactory for industries having multiple depot locations, or industries using a heterogeneous set of service providers to service a heterogeneous set of service points.

[0010] For example, in the home health care industry, the skill set of a service provider must be correlated to the type of service required by a patient. One nurse may have the skill, and the necessary license, to redress a wound, or draw blood, but may not have been trained to insert a catheter. If that type of service is required by a patient, it would be inappropriate, and costly, to schedule a nurse without the appropriate skill level to visit that patient. Furthermore, particularly in the health care industry, time may be of the essence. If a patient requires an insulin injection between the hours of 7-9 am every day, it would be disastrous to have a routing solution that caused a nurse to arrive at 12 pm.

[0011] Modern methodologies have simply failed to deal with the problem of optimizing routes for a set of service providers, each of which have unique skills, perhaps departing from geographically distinct service points, that service a set of heterogeneous service points, also geographically dispersed.

[0012] Therefore, a methodology is needed that provides a routing solution that considers any of a number of selected parameters, such as the skills of the service providers, the needs of the service points, the preferences of both the service providers and the service points, in determining an optimum solution.

[0013] In addition, a methodology is needed for optimizing routing solutions for heterogeneous service points, using heterogeneous service providers, where each of the parameters used in obtaining the routing solution (e.g., skills, licenses, preferences) is individually configurable, both in terms of whether they are considered in obtaining the routing solution, and in terms of how much weight is applied to them in obtaining a routing solution.

[0014] For example, in the instance mentioned above where a patient requires an insulin injection between the hours of 7-9 am every day, while it would be disastrous to schedule a visit at 12 pm, it may be possible to schedule a visit at say 7:30 am. Another example would be if the service provider available to make the insulin visit did not desire to work before 12 pm, or was already on overtime before making the insulin visit. Certain costs should be considered before selecting that provider for that visit. And, depending on the providers window of availability, and his/her accumulated hours for the week, the weighting applied to their cost could be non-linear. What is therefore needed is a

routing system that allows linear and non-linear penalty to be applied to particular parameters, that result in a total optimal solution.

SUMMARY

[0015] To address the above-detailed deficiencies, it is an object of the present invention to provide a method for delivering an optimal routing solution that allows both linear and non-linear penalty to be applied to selected parameters in determining the complete operational cost of a routing solution.

[0016] Yet another object of the present invention is to provide a method for obtaining an optimal routing solution that considers the total costs associated with any particular route, including configurable weighting of a skill or license requirement not being met, a preference being met or not met, as well as a number of other parameters.

[0017] It is therefore a feature of the present invention to provide a method for calculating an optimal routing solution given a plurality of service points and a plurality of service providers, the plurality of service providers having a plurality of parameters that are selectably weighted. The method includes: selecting at least one of the plurality of parameters to weight; specifying a weight to be applied to the selected at least one of the plurality of parameters; and scoring a plurality of routing solutions utilizing the specified weight applied to the at least one of the plurality of parameters.

[0018] An advantage of the present invention is that an operator can configure a penalty scheme of direct or indirect costs to be applied to any parameter used in obtaining an optimum routing solution.

[0019] In another aspect, it is a feature of the present invention to provide a method for scheduling routes using heterogeneous service providers to service heterogeneous service points, the service points being geographically dispersed, the service points having a plurality of service point profiles, and the service providers having a plurality of service provider profiles. The method includes: providing a service point visit plan for at least one of the plurality of service points; specifying a configurable weight to be applied to a selectable parameter within one of the plurality of service provider profiles; and scoring a plurality of routing solutions to service the at least one of the plurality of service points, utilizing the service point profiles, the service provider profiles, and the weighted selectable parameter; wherein an optimal routing solution is obtained from the scored plurality of routing solutions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] These and other objects, features, and advantages of the present invention will become better understood with regard to the following description, and accompanying drawings where:

[0021] FIG. 1 is a pictorial representation of a city map illustrating a plurality of service points that are geographically dispersed that must be serviced by a plurality of service providers.

[0022] FIG. 2 is a pictorial representation of a suboptimum routing solution for servicing a plurality of homogeneous service points.

[0023] FIG. 3 is a pictorial representation of an optimal routing solution for servicing a plurality of homogeneous service points.

[0024] FIG. 4 is a block diagram illustrating components within an embodiment of the present invention.

[0025] FIG. 5 is a computer screen illustrating an operations manager according to the present invention.

[0026] FIG. 6 is a computer screen illustrating general information associated with a service provider according to the present invention.

[0027] FIG. 7 is a computer screen illustrating particular details associated with defining a service provider according to the present invention.

[0028] FIG. 8 is a computer screen illustrating particular skills associated with a service provider in the health care industry according to the present invention.

[0029] FIG. 9 is a computer screen illustrating a service provider's work availability for a particular week according to the present invention.

[0030] FIG. 10 is a computer screen illustrating general information associated with a service point according to the present invention.

[0031] FIG. 11 is a computer screen illustrating preferences of a service point according to the present invention.

[0032] FIG. 12 is a computer screen illustrating definition of a visit plan for a particular service point, according to the present invention.

[0033] FIG. 13 is a computer screen illustrating relational definitions between skills and tasks within the health care industry, according to the present invention.

[0034] FIG. 14 is a computer screen illustrating router controls and scoring controls for obtaining an optimal routing solution, according to the present invention.

[0035] FIG. 15 is a graph illustrating a procedure for specifying linear and non-linear penalty to be applied to selected parameters within service provider and service point profiles.

[0036] FIG. 16 is a flow chart illustrating a procedure according to the present invention for obtaining an optimal routing solution for a given set of service providers, and a given set of service points, using a predetermined visit plan.

DETAILED DESCRIPTION

[0037] Referring to FIG. 1, a map 100 is shown. The map 100 illustrates a portion of a city having residences 102, 104 and 106 that are geographically dispersed. The residences 102-106 are defined by their longitude and latitude, and are associated with street addresses, or other forms of reference, within the map 100.

[0038] Also shown on the map 100 are health care providers 108 and 110, located at the residences 102 and 104, respectively. The health care providers 108, 110 are providing in home health care services to patients living at the residences 102, 104. Also shown is a third residence 106. Health care services at this residence are to be performed by either the provider 108, or the provider 110. The routing of the providers 108, 110 to the residences 102, 104, and

subsequently to the residence **106** must consider parameters such as: 1) the type of service required by the patient, 2) the skills required to perform the service, 3) the current license status of the providers **108, 110**, 4) the preferences of the patient at the residence **106**, 5) the preferences of the providers **108, 110**, 6) the materials required to perform the service, and 7) the availability of the providers **108, 110** within a time frame required by the patient. However, heretofore such routing of providers only considered the distance that had to be traversed by a particular provider, and possibly the timeframe in which a service had to be performed. The parameters such as skills, licenses, preferences, and materials have either been ignored, or the routing solutions used have not been optimal. An example of a sub optimum routing solution is shown in **FIG. 2**, to which attention is now directed.

[0039] In **FIG. 2**, a map **200** is shown having 16 homogenous service points **202** that are to be serviced by two homogenous service providers **204** and **206**. Homogenous service points and service providers imply that the services required by any of the service points **202** are identical, and that either of the service providers **204, 206** are capable of servicing any of the service points **202**.

[0040] For purposes of illustration, the service providers **204** and **206** begin their routes at geographically distinct locations, and upon completion of their routes, return to their originating location. If it is presumed that none of the service points **202** have time windows during which service must be provided, that the service providers **204, 206** are available at the same time, and that both service providers **204, 206** are capable of servicing eight service points in a day, one routing solution for the service providers is shown by routes **210** and **212**.

[0041] What should be clear from the map **200** is that both of the routes **210, 212** include legs (travel between two service points) that are of considerable distance. One skilled in the art should recognize that these distances are sub optimal because they require the service providers **204, 206** to spend too much time traveling between the service points **202**. In general, the service providers **204, 206** are either employees of a service company, or are contractors hired by a service company. In either case, a service company is primarily concerned with providing service to the greatest number of patients, in the least amount of time, so as to reduce their overall operating expenses. If either of the service providers **204, 206** make poor choices in their route, or are provided with sub optimum routes, valuable time and considerable expense is wasted.

[0042] Now referring to **FIG. 3**, a map **300** is shown. The map **300** contains 16 homogeneous service points to be serviced by two service providers **304, 306**. A routing solution is shown that provides two routes **310, 312** for the service providers **304, 306**, respectively. However, in **FIG. 3**, the routes **310, 312** are optimal to reduce the amount of time the service providers **304, 306** spend traveling between the service points **302**. One skilled in the art will appreciate that the routing solution provided in **FIG. 3** is optimal over that of **FIG. 2** to reduce many of the operating costs associated with servicing the service points, and ultimately to increase revenue for the service company.

[0043] Generally, service companies have operating costs that include travel time, gasoline and other transportation

expenses, and hourly wages for the service providers. In addition, with less time spent traveling between service points, it is possible that the service providers **304, 306** could service more than the eight service points **302** shown, thereby creating further revenue for their service company.

[0044] However, as explained in the Background above, route optimization methodologies have heretofore been concerned with servicing a set of homogeneous service points using homogeneous providers. Such methodologies have failed to deal with industries requiring route optimization of service providers, each of which have unique skills or licenses, or of heterogeneous service points, each requiring a different service or skill level, or allowing service points to state preferences regarding the provider, or the desired time of service, etc. As a result, service companies have forgone analyzing route solutions based on a total route cost model. That is, a route cost model that considers direct costs such as wages (salary, hourly, overtime, etc.) and transportation expenses, as well as real but indirect costs, such as skill deficiencies, unmet preferences, servicing outside of time windows, etc. Instead, they have either derived a routing solution based solely on geographic distance, perhaps including time windows, or have treated service providers and service points homogeneously. In some instances, service companies have neglected route optimization altogether.

[0045] What will now be described is an embodiment of the present invention that provides an optimal routing solution for industries having heterogeneous service providers that service a heterogeneous set of service points. Referring to **FIG. 4**, a block diagram **400** is shown illustrating an embodiment of the present invention. The invention includes an operator interface **410** coupled to a route engine **420** and a representation model **430**.

[0046] The user interface **410** provides a computer mechanism for inputting all of the information associated with determining an optimal routing solution for a given set of service providers and service points, and for displaying and analyzing resultant routing solutions.

[0047] The user interface **410** is coupled to a representation model **430** which stores the data required for determining an optimal routing solution for a particular visit plan (further described below). The representation model **430** includes a service point profile, a service provider profile, a scoring model, information on time windows associated with a particular visit plan, preferences for both service providers and service points, and a map database for a particular service area. Information is input into the representation model **430** via the user interface **410**.

[0048] The representation model **430** is coupled to a route engine **420**. The route engine **420** implements one of a number of alternative algorithms for deriving an optimal routing solution, given a set of service providers and a set of service points. One skilled in the art will appreciate that the use of meta-heuristics to breed a set of solutions is known. However, meta-heuristics tend to be slow, and often engage valuable processing time "breeding" less than optimal solutions. Heuristics, on the other hand, tend to provide solutions in a more expedient manner, but fail to search broadly the multimodal graph. The route engine **420** therefore combines the use of meta-heuristics, which are robust but slow and have no clear stopping rules, with heuristics, which are fast

but not exhaustive, to obtain a generation of possible solutions. Within each generation, however, a number of less than desirable possibilities are created. The route engine **420** therefore uses a technology termed "anti-niching" to essentially prevent premature convergence. The combination then of meta-heuristics, with heuristics and anti-niching techniques, to produce an optimal routing solution in an expedient manner is fully described in U.S. patent application, Ser. No._____ (Docket EPI:1003), filed_____, entitled "Multi-layer Engine Using Generic Controls for Optimal Routing Scheme", by Mark T. Lane, Ph. D., et al., which is hereby incorporated by reference. One skilled in the art will appreciate however, that an optimum routing solution for a set of heterogeneous service providers, given a set of heterogeneous service points, may be accomplished using any of a number of known routing methodologies in combination with the teachings of the present invention.

[0049] Once the route engine **420** has calculated an optimal routing solution, using the data in the representation model **430**, the solution is provided to the user interface **410**. At this point, the user interface can either deliver individualized routes to a set of service providers, or can provide a graphical overview of the routing solution to allow an operator to modify the solution, as desired.

[0050] Now referring to **FIG. 5**, a screen shot is provided of an operations manager portion **500** of the user interface **410**. The operations manager **500** includes a Navigation bar **510**, an Actions icon set **520**, a Calendar **530**, and a Status box **540**. The Navigation bar **510** allows an operator to select one of a number of display screens, corresponding to service points (patients) **512**, service providers (providers) **514**, service provider schedules (schedules) **516**, or area maps **518**. The Actions icon set **520** allows an operator to initiate the generation of a routing solution (schedule), to insert a visit in a least cost manner, within the existing service provider's schedules (Insert Visits), or to archive a previously generated schedule (Archive Schedule), by pressing an appropriate icon. The Calendar **530** allows a user to select a particular day, or week, for which a routing solution will be generated.

[0051] The Status box **540** provides the user with information regarding the status of service points and service providers for the day selected on the calendar **530**. In one embodiment, the Status box **540** alerts the user of patient issues including: unscheduled visits, unassigned supervisor visits, and certification necessary. A "light" in a graphical LED next to unscheduled visits indicates that a visit has been scheduled in a visit plan for a particular service point, which has not yet had a service provider assigned to it. A light next to unassigned supervisor visit indicates that a service provider may have been assigned to visit a service point, but that the assigned service provider requires supervision, and a supervisor has not yet been assigned. This is particularly important in the health care industry where certain providers can perform some tasks independently, such as bathing a patient, redressing a wound, or giving a shot, but are in training when performing other tasks such as taking blood or inserting a catheter. A light next to certification necessary indicates that although a service provider has been scheduled to visit a service point, the assigned service provider does not have the license, or certification necessary to perform the required services.

[0052] The Status box **540** also includes information with respect to service providers for the day selected in the calendar **530**. The information includes: resource deficiency, skill deficiency, and preference failure. A light next to resource deficiency indicates that there are too many service points to be visited by the available set of service providers. An alert in this area would cause the user to either contract with an additional service provider, or possibly reschedule one or more of the visits for another day. A highlight next to skill deficiency indicates that although all of the service points have a service provider scheduled to visit them, one of the scheduled service providers does not have either the skills, or the certification necessary to perform the required service. A light next to preference failure indicates that although visits may have been scheduled to all service points, particular preferences, either of a service point or a service provider, may not have been met. Alerts on any of these status indicators may cause an operator to develop an alternative visit plan, and generate another route solution, or contact an additional service provider to overcome any deficiency.

[0053] Now referring to **FIG. 6**, a screen shot **600** is shown associated with inputting general information respecting a service provider. In one embodiment, the screen **600** is presented when an operator selects I/O icon **514** on the operations manager **500**. The screen shot **600** has 4 tabs at the top denoted: General, Details, Skill Maintenance and Work Hours. Each of these will be described below with reference to FIGS. 6-9. The screen shot **600** includes fields for a provider name **602**, a dispatch method **604**, contact information **606**, an address **608**, and job description-license **612**. The provider name field **602** allows an operator to maintain the name of a service provider. The dispatch method field **604** defines how the service provider is to be contacted for scheduling purposes. In one embodiment, the service provider can be contacted by mail, by fax, by email, or simply by handing him/her a schedule at a designated location. The contact information field **606** provides telephone contact information for the provider. The address field **608** provides street address information associated with the residence of the service provider. This is particularly important when generating an optimal routing solution if the service provider begins or ends his/her route from his/her home address. A geolocate button **610** is provided within the address field **608** to calculate an electronic position index, such as latitude, longitude, and street segment, etc., on the electronic map used in generating the routing solution. The job description-license field **612** particularly identifies the skills and the licenses held by the service provider. In one embodiment, fields **602-606** are used primarily by the user interface **410** in generating reports associated with service providers, while fields **608-612** are used primarily by the route engine **420** in calculating an optimal routing solution, as will be further described below.

[0054] Referring now to **FIG. 7**, a screen shot **700** is shown which includes further details on the service provider that was input in **FIG. 6**. The fields shown in **FIG. 7** include personal information **702**, medical history **704**, licensing and training **706**, and employment information **708**. The personal information field **702** may be used for employment and tax reporting, but can also provide driving/insurance information to insure the legality of scheduling a particular service provider to drive a route. The medical history field **704** can be used to maintain the health status of the service

providers. The licensing and training field **706** may be used to track the existence or the status of a required license for performing particular services. The employment information field **708** includes information such as the pay rate of a service provider, and whether the service provider is an independent contractor, or an hourly or salary employee.

[0055] Referring now to **FIG. 8,** a screen shot **800** is shown that defines the skills obtained by a particular service provider. The screen **800** includes a skills list **802** and a skills assigned field **804**. The skills list **802** contains a listing of all the skills for a particular industry which must be individually tracked. The skills listed in field **802** are a representative subset of skills required in the home health care industry. It should be appreciated that other industries have different sets of skills which must be tracked for their service providers. The skills assigned field **804** define the skills obtained by the particular service provider for which information is being input.

[0056] Referring now to **FIG. 9,** a screen shot **900** is shown which illustrates the work hours associated with a particular service provider. In one embodiment, the screen **900** provides a week at a glance format indicating the availability of a particular service provider to perform services to scheduled service points.

[0057] The information shown in the screens **600-900** provide the information necessary to utilize a service provider within a routing solution. As will be further described below, with reference to **FIG. 14,** selected fields within screens **600-900** may be used by the route engine **410** in deriving an optimal routing solution. These fields include a service provider's availability, their assigned skills, their licensing information, their employment information (such as their pay rate), their job description-license (including the minimum number of service points per day that they require), and even their home address. Any one or more of the fields used to obtain an optimal routing solution is defined as a service provider profile.

[0058] Referring now to **FIG. 10,** a screen shot **1000** for defining parameters of a service point is shown. Within the home health care industry, service points are referred to as patients. A patient information field **1002** is provided to input general patient information such as their name, social security number, etc. In addition, a patient address field **1004** is provided to define a street address where services are to be administered. Within the address field **1004** is a geocode button **1006** to cause the street address of the patient to be electronically indexed on an electronic map. The electronic index is then used in determining a routing solution to the patient.

[0059] Referring now to **FIG. 11,** a screen shot **1100** is shown which allows preferences to be defined for a particular service point. The screen **1100** includes a preference list **1102**, a patient selected preferences list **1104**, a providers list **1106**, a preferred providers list **1108**, and a non-preferred providers list **1110**. The preferences list **1102** contains a list of all available preferences that may be applicable to any service point. From the list **1102**, particular preferences may be selected to apply to an individual service point. The selected preferences will then appear in the patient preferences list **1104**. A list of all possible service providers is provided in list **1106** from which preferred and non-preferred service providers may be selected. The preferred

providers for a particular service point will appear in list **1108**, while the non-preferred providers will appear in list **1110**.

[0060] Referring now to **FIG. 12,** a screen shot **1200** is shown for developing a visit plan for a particular service point. In one embodiment, the screen **1200** includes a 10 week calendar for defining services to be performed for the service point. A service visit is created by selecting a visit type from a visit type list **1202**, and dropping the visit type onto the day, or series of days requiring service. The visit types correspond to the type of service provider that is required by the particular service point. For example, in **FIG. 6,** a job description-license field **612** is provided to associate predefined license types to a particular service provider. In **FIG. 1200,** those license types are instantiated onto a particular day, or series of days to qualify the type of service provider that is required. Additionally, the particular tasks that must be performed on a particular day are selected from a task list **1204**, and dropped onto the instantiated visit type. Thus, by instantiating a visit type, and a task on a particular day, an operator can define both the type of service provider that is required (i.e., the license that the service provider must hold to perform the service), and the tasks to be performed at the service point.

[0061] The information shown in the screens **1000-1200** provide the information necessary to utilize a service point within a routing solution. As will be further described below, with reference to **FIG. 14,** selected fields within screens **1000-1200** may be used by the route engine **410** in deriving an optimal routing solution. These fields include the service point address, service point preferences, and service point selected and non-selected providers. Any one or more of the fields used to obtain an optimal routing solution is defined as a service point profile.

[0062] Referring now to **FIG. 13,** a screen shot **1300** is shown where relationships are established between required tasks to be performed, and the set of skills required to perform the tasks. More specifically, screen **1300** includes a task list **1302**, a skill list **1304**, and a skills required for a task list **1306**. For each task in the task list **1302**, one or more of the skills listed in the skill list **1304** must be selected. The task list **1302** corresponds to the tasks or services that may be selected in the visit plan shown in **FIG. 12**. The skill list **1304** corresponds to the list of skills obtained by a service provider, as defined above in **FIG. 8**. By associating skills required for a particular task within **FIG. 1300,** a relationship is created between services to be performed at service points, and a set of service providers that have obtained the skills necessary to perform those services.

[0063] The above discussion of FIGS. 5-13 provides all of the information necessary to define a service provider profile for a heterogeneous set of service providers (having different skills, preferences, originating locations, licenses, etc.), and a service point profile for a heterogeneous set of service points (having different locations, different service type requirements, different license and skill requirements, different preferences, etc.) This information is stored within the representation model **430** to be used in obtaining an optimal routing solution, as will now be described below, with reference to FIGS. 14-15.

[0064] Referring to **FIG. 14,** a screen shot **1400** is provided to illustrate some of the controls that may be used in

obtaining an optimum routing solution. Within a router control field **1402** are two options available for driving a router solution. The first control, "Include skill base/preferences", is a binary control that when selected, generates routing possibilities using the skills/licenses, preferences parameters that were defined in FIGS. 5-12. A second control, "Penalize simultaneous visits", causes the route engine to penalize a routing solution that has two service providers overlap their services at a common service point.

[0065] Also within **FIG. 14** is a penalty field **1404**. The penalty field **1404** allows an operator to create a penalty to be applied to either a skill deficiency, or a preference penalty. That is, for possible route solutions that do not contain the appropriate skill level for the service required, or is not able to comply with preferences specified by a service point, a negative penalty is applied to those routes.

[0066] Also shown within **FIG. 14** are contract labor rate fields **1406**. These fields allow an operator to associate real costs with using outside contractors to perform particular services. These costs, along with the salary wages defined for employed service providers, are factored into all possible routing solutions, so that a least cost solution can be obtained.

[0067] Finally, a mileage field **1408** is provided. The mileage field **1408** allows an operator to create a cost penalty to all distances driven in any possible routing solution.

[0068] Thus, **FIG. 14** allows a user to score a routing solution by assigning costs or weights to routing solutions using a number of different parameters. The parameters include: skills being met or not met; preferences being met or not met, simultaneous visits scheduled; and mileage cost.

[0069] Furthermore, although skills base and preferences were treated together in field **1402**, one skilled in the art should appreciate that any of the parameters associated with scoring a routing solution may be treated individually. In addition, both linear and non-linear penalty may be selectively applied to some parameters such as time windows.

[0070] While not shown in **FIG. 14**, the present invention employs a technique of converting each of the parameters in the service provider profile, and the service point profile into a direct cost or an opportunity cost for not being met. This means that there is a cost associated with: reimbursing a service provider for drive distance; not making a service point time window; not meeting a license requirement; not meeting a skill requirement; not meeting a service preference; not having the materials required to meet a service point need; not meeting a requirement for simultaneous service providers at a service point (such as when supervision is required); not starting or completing a service within a service provider's allocated work hours; paying a salary employee versus an hourly employee versus a contractor; interrupting a route to refill inventory, etc. By applying a direct, or indirect cost to each of the parameters being met or not met, a complete operational cost model may be used by the route engine **420** in the optimization process.

[0071] In addition, while not shown in **FIG. 14**, the present invention allows non-linear equations to be used in the penalty or costing of any of the specified parameters. For example, in determining a routing solution, it may be advantageous to pay a contractor to work an hour past his/her regularly scheduled time in order to complete a possible routing solution. A weight or cost of 1.5x hourly wage may be applied to that hour. However, if that same contractor is used an additional hour, a weight or cost of 6.0x hourly wage may be applied.

[0072] Another example where non-linear weighting may be advantageous is in scoring the parameter of meeting or not meeting a particular time window. For example, if a service point has a time window of 10 am-12 pm wherein service must be provided, a penalty of 0 should be applied to a solution that meets that time window. A small penalty may be applied to a routing solution that has the service provider arriving either 15 minutes early, or 15 minutes late. However, a fairly severe penalty would be applicable for a routing solution that has the service provider arriving an hour on either side of the time window. In addition, the early and late penalties can be configured differently. For example, if the provider arrives early, s/he can always wait for the begin time. But if s/he arrives late, the customer satisfaction level drops and may therefore be considered in the optimization.

[0073] One technique for allowing a user to specify both linear and non-linear penalty of selected parameters is shown in **FIG. 15**, to which attention is now directed. **FIG. 15** provides a graph **1500** where a cost multiplier is represented on a Y-axis **1502**, and time variation from either a time window, or from desired work hours, or overtime, is shown on an X-axis **1504**. In one embodiment of the present invention, a user is provided with a graph similar to the graph **1500**, and is allowed to input a line or a curve to specify whether linear or non-linear penalty is to be applied to selected parameters, and what the penalty should be for the selected parameters. For example, graph **1500** includes specified penalty for two particular parameters. The first parameter is shown by parabola **1506**. The penalty provided by parabola **1506** is to be applied to routing solutions that vary from specified service point time windows. For example, if a routing solution considers a route that is 60 minutes before a specified time window begins (−60 minutes), then a penalty of approximately 1.25x is to be used. However, if a routing solution considers a route that is 120 minutes before a specified time window begins (−120 minutes), then a penalty of approximately 2x is to be used.

[0074] A second parameter specified in graph **1500** applies to configurably weighting of cost associated with time outside an employee's desired work hours. For example, an employee (or a contractor) may desire to work between the hours of 1 pm and 5 pm. However, they may also indicate a willingness to work between 10 am and 8 pm, albeit at increased wages. A line **1508** is shown that indicates the penalty for a particular employee. Line **1508** shows that wages are 1x as long as the routing solution is within his/her desired work hours. However, variation from the desired work hours has the following effect: 2x wages for an hour either side of the desired work hours; 2.5x for 1-3 hours either side of the desired work hours; and 4x for more than 3 hours either side of the desired work hours.

[0075] One skilled in the art should appreciate that the parabola **1506**, and the line **1508** are exemplary only. That is, the scales used for the Y-axis **1502**, and the X-axis **1504** could easily be changed to reflect other requirements. For example, the scale on the Y-axis **1502** could include non-linear linear penalties such as X^2, $X^{2.5}$, or X^3. In addition,

the parameters to which weighting is applied could include any of the parameters described above, but should at least include: a) time outside of specified service point time windows; b) time outside of desired work hours; c) time outside of available work hours; and d) overtime.

[0076] Moreover, the user-interface that allows specification of linear and non-linear penalty could be textual rather than graphical. For example, a user could be allowed to enter an equation to be associated with weighting of a specified parameter. For example, an equation for variance from a specified service point time window could be: if $tsched<Tstart$, $3*(Tstart-tsched)^2$, if $tsched>Tend$, $3*(tsched-Tend)^2$, where tsched is the time specified for a particular route, and Tstart/Tend are start and end time for a service point time window. While the present invention allows a user to prescribe any equation to be used for selected parameters, it has been determined that the graphical interface shown in FIG. 15 is more readily understood. The manner of prescribing the penalty to be applied to selected parameters is of less interest to the present invention than that both linear and non-linear penalty can be applied, in whatever form, to selected parameters, when determining an optimal routing solution.

[0077] Referring now to FIG. 16, a flow chart 1600 for obtaining an optimal routing solution, according to the present invention, is provided.

[0078] Flow begins at block 1602 wherein an operator inputs service parameters. The service parameters that must be input correspond to the parameters within the service point profile and the service provider profile. That is, the service parameters identify all of the service providers and service points, their skills, licenses, preferences, locations, availability, and other requirements. This was described above with reference to FIGS. 5-11, 13. Flow then proceeds to block 1604.

[0079] At block 1604, the scoring model is defined for a particular routing solution. That is, costs or weights, linear and non-linear, are applied to selected parameters used in scoring routing solutions. This was described above with reference to FIG. 14. Flow then proceeds to block 1606.

[0080] At block 1606, a service point visit plan is created for each of the service points. This was described above with reference to FIG. 12. Flow then proceeds to block 1608.

[0081] At block 1608, the service point profiles, the service provider profiles, the visit plans, and the scoring model are provided to a route engine, such as the route engine 420. As described above with reference to FIG. 4, a number of alternative routing algorithms could be used, combined with the parameter control, penalty and complete operational cost model of the present invention to obtain an optimal routing solution. Flow then proceeds to block 1610.

[0082] At block 1610, the route engine 420 provides an optimal routing solution to the user interface 410, as described above. Flow then proceeds to decision block 1612.

[0083] At decision block 1612, a determination is made as to whether the user desires to insert a particular service point into the route of a particular service provider. If not, then flow proceeds to block 1616 where the generation of an optimal routing solution is completed.

[0084] If an operator desires to insert a particular service point into the route of a particular service provider, flow proceeds to block 1614. At this point, the user selects the visit that is to be moved, and drops this visit into the route of an alternative service provider. Flow then proceeds back to block 1608. The route engine then generates an optimal routing solution, but restricts the operation to the two service providers affected by the insertion.

[0085] Although the present invention and its objects, features, and advantages have been described in detail, other embodiments are encompassed by the invention. For example, the embodiment shown above with reference to FIGS. 5-13 was particularly illustrated with reference to the home health care industry. However, one skilled in the art will appreciate that the example used was simply for ease of illustration. Other industries, such as the utility industry (gas, electric, telecommunication), hospital care, or any other service industry where the service providers and service points are heterogeneous are also applicable. In addition, only a subset of skills/licenses were shown for the home health care industry. Any set of parameters, skills, licenses, tasks, etc., for any industry, may be incorporated into the present invention, and may be individually selected, or grouped together, to obtain criteria upon which linear or non-linear scoring is applied. Variations in parameter selection, and scoring will drive the routing optimization according to an operator's particular criteria, and according to his industry.

[0086] Those skilled in the art should appreciate that they can readily use the disclosed conception and specific embodiments as a basis for designing or modifying other structures for carrying out the same purposes of the present invention without departing from the spirit and scope of the invention as defined by the appended claims.

We claim:
1. A method for calculating an optimal routing solution given a plurality of service points and a plurality of service providers, the plurality of service providers having a plurality of parameters that are selectably weighted, the method comprising:

a) selecting at least one of the plurality of parameters to weight;

b) specifying a weight to be applied to the selected at least one of the plurality of parameters; and

c) scoring a plurality of routing solutions utilizing the specified weight applied to the at least one of the plurality of parameters.

2. A method for calculating an optimal routing solution given a plurality of service points and a heterogeneous plurality of service providers, the heterogeneous plurality of service providers having a plurality of parameters that are selectably weighted, the method comprising:

a) selecting at least one of the plurality of parameters to weight;

b) specifying a weight to be applied to the selected at least one of the plurality of parameters; and

c) scoring a plurality of routing solutions utilizing the specified weight applied to the at least one of the plurality of parameters.

3. The method for calculating an optimal routing solution, as recited in claim 2 wherein the plurality of parameters comprise:

i) a service provider's start time; and

ii) a service provider's end time.

4. The method for calculating an optimal routing solution, as recited in claim 3 wherein the weight that is applied to the selected at least one of the plurality of parameters controls a cost associated with a routing solution that falls outside of the service provider's start time or end time.

5. The method for calculating an optimal routing solution, as recited in claim 2 wherein the weight that is applied to the selected at least one of the plurality of parameters is non-linear.

6. A method for scheduling routes using heterogeneous service providers to service heterogeneous service points, the service points being geographically dispersed, the service points having a plurality of service point profiles, and the service providers having a plurality of service provider profiles, the method comprising:

a) providing a service point visit plan for at least one of the plurality of service points;

b) specifying a configurable weight to be applied to a selectable parameter within one of the plurality of service provider profiles; and

c) scoring a plurality of routing solutions to service the at least one of the plurality of service points, utilizing the service point profiles, the service provider profiles, and the weighted selectable parameter;

d) wherein an optimal routing solution is obtained from the scored plurality of routing solutions.

7. The method for scheduling routes, as recited in claim 6 wherein the configurable weight is specified using a graphical user interface.

8. The method for scheduling routes, as recited in claim 6 wherein the configurable weight is specified by entering a textual non-linear equation.

9. The method for scheduling routes, as recited in claim 6 wherein the configurable weight allows a non-linear cost to be applied to a routing solution at variance with a service provider profile.

10. The method for scheduling routes, as recited in claim 7 wherein a variance from a service provider profile comprises:

i) scheduling a service provider to visit a service point outside the service provider's designated work hours.

11. The method for scheduling routes, as recited in claim 8 wherein a variance from a service provider profile comprises:

i) scheduling a service provider to visit a service point, causing the service provider to work overtime.

12. The method for scheduling routes, as recited in claim 9 wherein a variance from a service provider profile comprises:

i) scheduling a service provider to visit a service point outside of the service provider's desired work hours.

13. The method for scheduling routes, as recited in claim 6 further comprising:

e) specifying a second configurable weight to be applied to a selectable parameter within one of the plurality of service point profiles; and

f) scoring a plurality of routing solutions to service the at least one of the plurality of service points, utilizing the second configurable weight.

14. The method for scheduling routes, as recited in claim 11 wherein the second configurable weight allows a non-linear cost to be applied to a routing solution at variance with a service point profile.

15. The method for scheduling routes, as recited in claim 14 wherein a variance from a service point profile comprises:

i) scheduling a service provider to visit a service point outside of a service point time window specified in one of the plurality of service point profiles.

16. A method for scheduling routes using heterogeneous service providers to service heterogeneous service points, the service points being geographically dispersed, the method comprising:

a) providing a plurality of service point profiles, corresponding to a plurality of service points;

b) providing a plurality of service provider profiles, corresponding to a plurality of service providers;

c) providing a service point visit plan for at least one of the plurality of service points; and

d) scoring a plurality of routing solutions to service the at least one of the plurality of service points, utilizing the service point profiles and the service provider profiles, the scoring comprising:

(1) assigning a weight to selected parameters within the plurality of service point profiles and within the plurality of service provider profiles;

(2) utilizing a route engine to generate the plurality of routing solutions according to the service point visit plan; and

(3) scoring the plurality of routing solutions utilizing the weighted selected parameters.

e) wherein an optimal routing solution is obtained from the scored plurality of routing solutions.

17. The method for scheduling routes, as recited in claim 16, wherein the weight that is assigned to selected parameters is non-linear.

18. The method for scheduling routes, as recited in claim 16, wherein the weight that is assigned to selected parameters is selectably linear or non-linear.

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